New approaches to water and sewer services in permafrost areas Norman Wells, N.W.T.

W.W. Irwin

NEW APPROACHES TO WATER AND SEWER SERVICES IN PERMAFROST AREAS NORMAN WELLS, N.W.T.

by

W. W. Irwin
M. M. Dillon Limited
Edmonton, Alberta

1. INTRODUCTION

1.1 Community

The community of Norman Wells is located on the east bank of the Mackenzie River about 140 kilometers south of the Arctic Circle. It is the oldest resource based community in the Northwest Territories, having been founded in the 1920's when a major oil discovery was made at the site. In addition to servicing the 1,000,000 barrel per year refinery at its western edge, the settlement is the major regional administrative and distribution centre for the central Mackenzie Valley. The population of Norman Wells is about 400 persons and has been relatively stable for several years.

The community has an 1800 meter paved airstrip and is served five times a week by mainline jet from Edmonton and Yellowknife. During the summer months there is barge service from the railhead at Hay River - some 800 kilometers to the southeast.

Norman Wells lies within the discontinuous permafrost zone. The mean annual air temperature is -6°C and the ground temperature is -3°C at a depth of 15 to 30 meters. Thickness of permafrost is reported to be 45 to 60 meters and the active layer is reported to vary from .7 meters to 3.0 meters depending on cover and subsoil type.

1.2 Servicing Program

In the fall of 1975 two major problems were facing the government responsible for municipal servicing in Norman Wells. These were:

1) An aging and deteriorating utilidor system servicing a large part of the existing community, and
2) pressure for expansion of servicing in preparation for growth related to the then imminent Mackenzie Valley Pipeline.

Studies relating to these concerns were commissioned in the fall of 1975, and in early 1976, the Government of the Northwest Territories retained the firm of M. M. Dillon Limited to carry out a program of replacement and expansion of water distribution and sewage collection services in the community.

1.3 Scope of this Paper

This paper is an attempt to provide a brief overview of the design considerations; the development of system concept and design details; the construction techniques and problems, and the post-construction performance of the Norman Wells water and sewer system installed during the period from 1976 to 1978.

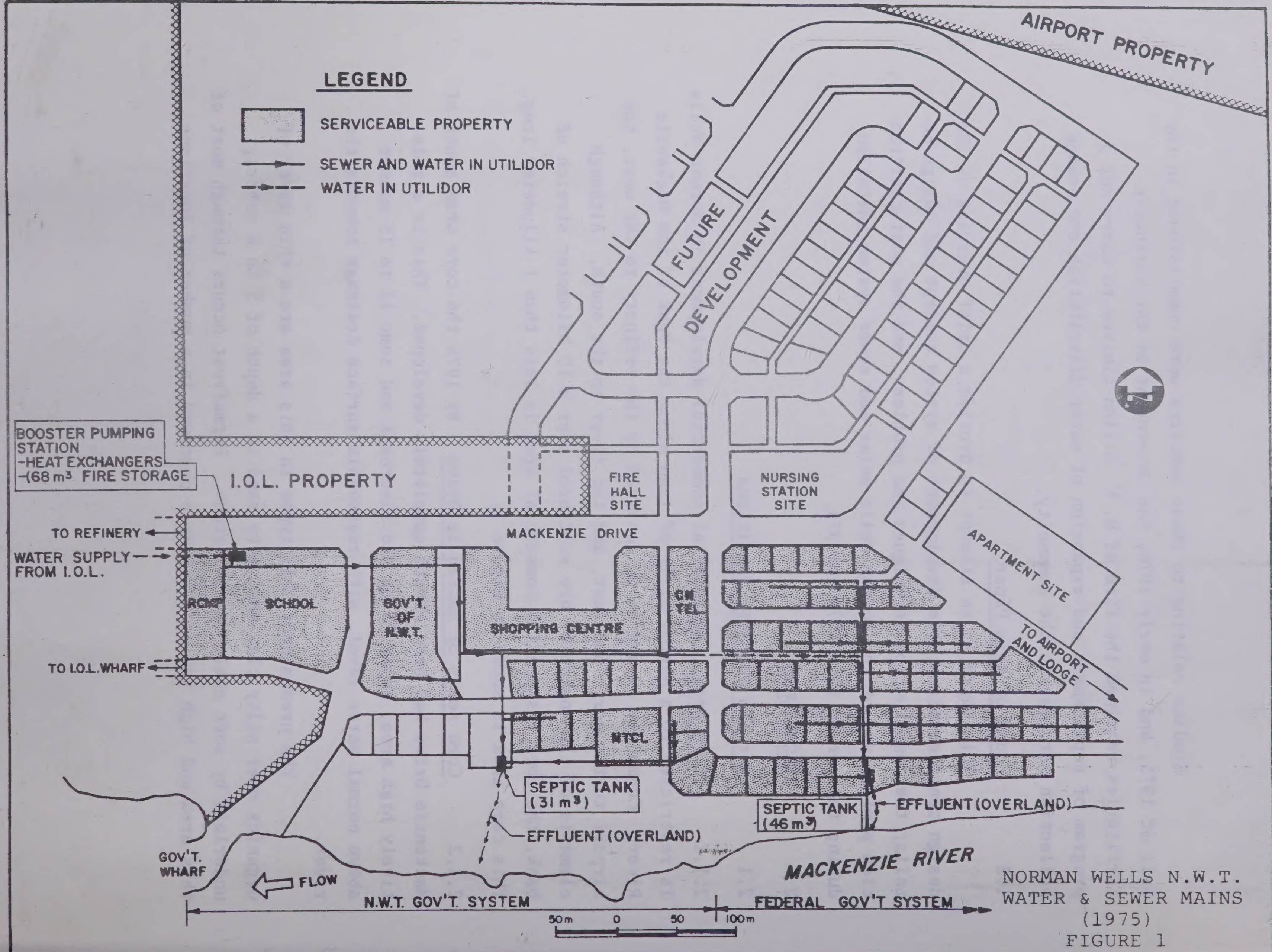
2 BACKGROUND

2.1 Terrain and Site Conditions

2.1.1 Core Area   Residential-commercial development in Norman Wells is restricted to a narrow strip of land along the bank of the Mackenzie River. Community expansion is confined by the refinery to the west, the airport to the north and east, and the river to the south. Although elements of the community are scattered over a 10 kilometer stretch of bank, the core residential-commercial area is less than 1 kilometer long. This core area is shown in Figure 1.

2.1.2 Core south of Mackenzie Drive   By 1975 the core area south of Mackenzie Drive had been almost completely developed. This is a relatively high area, adjacent to the riverbank and some 12 to 15 meters above normal water level, with reasonable surface drainage towards the river.

The predominant soil types in this area are a thin layer of organics over silty clay and silty sand to a depth of 5 to 8 meters, underlain by soft shale and limestone. Permafrost occurs through most of this area and high ice contents were observed in a number of locations.



NORMAN WELLS N.W.T.
WATER & SEWER MAINS
(1975)
FIGURE 1

During the course of development much of the area had been covered with a blanket of imported granular fill, ranging in thickness from a few centimeters to over a meter. Under some roadways a thick layer of spruce slash had been placed as an insulating blanket prior to filling.

Heated buildings in this area were either founded on piles to bedrock or supported on shallow footings on imported granular pads. All buildings were basementless and all residential buildings had skirted crawl spaces underneath the main floor.

2.1.3 Core north of Mackenzie Drive By the fall of 1975 site development of a core expansion area north of Mackenzie Drive was well underway. This is a less desirable low-lying muskeg area which rises gradually to the north as it approaches the esker on which the airport is located.

The predominant soil types in the southern two thirds of this area are a 1 to 2 meter layer of poorly drained organics underlain by frozen silty clays and silty sands. Shale bedrock occurs at a depth of about 6 meters. On the northern third of the site organics thin out to a few centimeters and drainage improves as the land rises.

Site development of this area involved ditching and some predraining in low lying areas followed by placement of a limestone and shale working blanket. The blanket was placed by end-dumping on top of the organics and varied in thickness from 1.2 meters minumum to over 2 meters as required to provide good surface drainage. The limestone was "quarry-run" material and ranged in size from a few centimeters to 3 cubic meter stones. Shale topping material was in the medium gravel size range. Differential settlements of up to .4 meters were reported in this fill after its first season in place.

2.2 Existing Services and Problems

2.2.1 History The Norman Wells area has been the scene of considerable utility system development for almost 40 years. A variety of above ground and buried systems have been designed and constructed by numerous agencies including the U.S. Army, Imperial Oil Limited, Transport Canada, Public Works Canada, and the Government of the Northwest Territories.

Because of the poor soil conditions and severe climate in the area many of these systems have failed after very short periods. Causes of failure have included inadequate insulation, degradation of permafrost, frost jacking of pilings, lack of integrity and durability of enclosures, and corrosion of piping. In general, each successive desidner has been aware of the shortcomings of previous designs and there have been continuing improvements in each generation of system

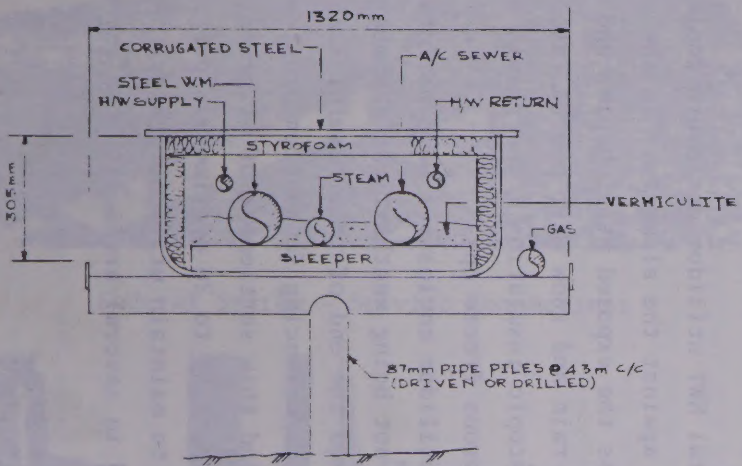
2.2.2 Existing Services 1975 In 1975 two service systems were in operation in the developed core of the community as shown in Figure 1. The western part of the core was serviced by the Government of the Northwest Territories and the eastern part by Public Works Canada.

Both systems were essentially above ground utilidor systems of the branch type with no recirculation of water. Branches in each system were graded towards septic tanks which discharged effluent high on the river bank in close proximity to residential areas.

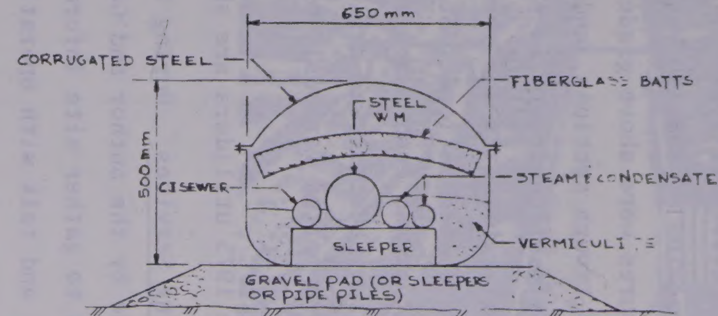
Treated water , steam and natural gas were purchased from Imperial Oil Limited at a metering station located on the west boundary of the community and were transported by utilidor to a booster pumping station which contained the following facilities:

- 68 m^3 fire station tank
- electric booster pump to maintain pressure in the community mains and a diesel fire pump
- truck fill point for unserviced water users
- steam to hot water heat exchangers plus back-up oil fired boilers for hot water tracing

From the booster pumping station services entered the Northwest Territories utilidor system. This was a relatively modern system constructed in 1972. The utilidor, as shown in Figure 2, consisted of a galvanized flat-top corrugated metal enclosure; insulated with styrofoam on the top and sides, and vermiculite on the bottom. Normal piping within the enclosure consisted of a 150 mm steel watermain, a 150 mm asbestos cement sewer, and 38 mm hot water supply and return lines for utilidor heating. The main branch of this utilidor also carried a 75 mm steam line to supply the Public Works Canada system. The utilidor was supported on 87 mm steel pipe piles drilled and/or driven nominally to bedrock.



N.W.T. SYSTEM



FEDERAL SYSTEM
(ONE STYLE)

TYPICAL CROSS-SECTIONS
OF EXISTING UTILIDORS
(1975)
FIGURE 2

The Public Works Canada utilidor system received steam and water from the Government of the Northwest Territories system. In 1975 this system was a hodge podge of different types of construction, built by a number of agencies over a period of some 20 years. Among the types of construction used for enclosures were above grade wood boxes, above grade corrugated metal arch and trough sections, and at or below grade corrugated metal pipes. One style of enclosure is shown in Figure 2. Insulation consisted primarily of fibreglass and vermiculite, although styrofoam beads and rock wool were also noticed. Steel pipe was generally utilized for watermains, steam and condensate lines; and sewers were generally cast iron. Utilidor heating was achieved by steam tracing. Utilidor enclosures were supported variously on steel pipe piles, gravel pads and timber sleepers.

Typical views of the 1975 utilidors are shown in Figure 3.

2.2.3 <u>Problems with Existing Services</u> During the winter of 1975-76 several site visits were made by the author and Government of the Northwest Territories engineers to gather site information, review documentation on existing systems, and talk with operations and maintenance personnel and local residents.

A number of major problem areas were identified:

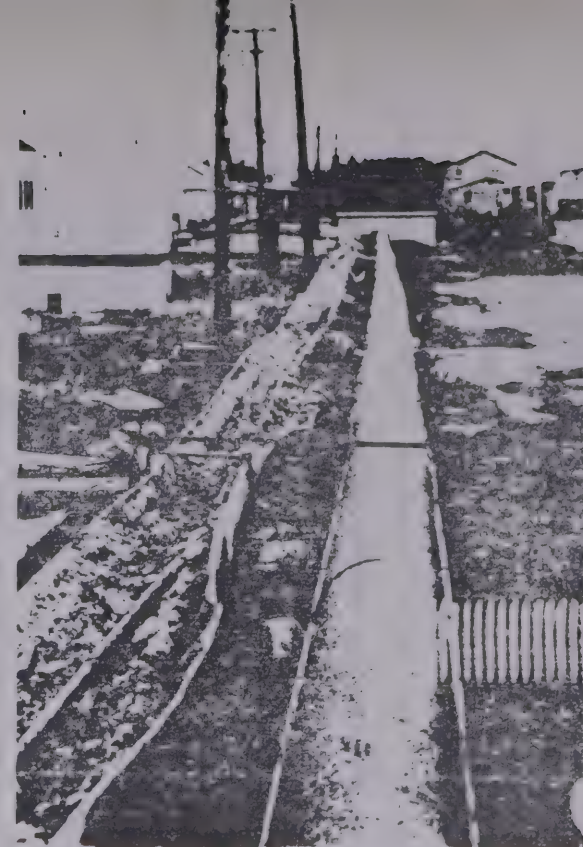
1) The corrugated metal NWT utilidor enclosure could not be adequately sealed against the elements. In the winter cold winds played across the exposed steel piping and in the spring and summer rain and snow melt poured into the enclosure ruining the hygroscopic insulation. The result was excessive heat loss and numerous freeze ups.

2) The Public Works utilidor enclosures were performing even less well. Apart from not being weathertight a number of the enclosures had reached the end of their useful life.

3) Both systems were experiencing foundation problems. Frost jacking of piles and thaw settlement of at grade systems was common. In some areas up to 20 centimeters per year of piling was being cut off to maintain utilidor grades. Reverse grades on sewers occurred in several areas with the accompanying blockages.

Federal System - Service Connections

N.W.T. System - Hydrant in Foreground



Federal System

TYPICAL UTILIDORS
CIRCA 1975

FIGURE 3

4) Insulation in both systems was not performing well. Hygroscopic insulation (fibreglass and vermiculite), used in both systems, was being destroyed by wetting. Non-hygroscopic insulation (styrofoam) in enclosures carrying steam lines was melting.

5) Steam lines were corroding and failing due to moisture intrusion in the utilidor enclosures.

6) The wide variety of enclosures and piping systems in use was a nightmare for maintenance personnel trying to stock components for emergency repairs. In addition many of the enclosures were not designed for easy access to the piping inside. Removing a dozen 13 mm bolts in -45°C weather to gain access to a valve usually meant that the enclosure top was left lying loose until the following spring.

7) Fire protection for the community was minimal. The Public Works Canada system contained only one 50 mm standpipe with a few meters of hose. Hydrants in the NWT system were also 50 mm standpipes, and although they were more numerous they were prone to freezing up.

8) Terminal water storage facilities were inadequate to provide buffering for demand fluctuations and fire reserve. At times the community was running out of water.

9) Terminal septic tanks for the two systems were unsightly, offensive, and potentially hazardous to users of the shoreline area.

After reviewing the problem areas identified, the following program for upgrading of existing services was established:

1) The existing Public Works Canada utilidor system would be replaced with a new system which would be turned over to the Government of the Northwest Territories.

2) The existing Government of the Northwest Territories utilidor system would be replaced where necessary with the remaining branches upgraded as required to keep them in service.

3) New terminal water storage facilities would be constructed.

4) The existing septic tanks and sewage outfalls would be abandoned and new sewage disposal facilities built.

3. DESIGN CONSIDERATIONS

3.1 General System Goals

In addition to reviewing site conditions and existing systems in Norman Wells, a partial review of other systems, operating or under construction in the Northwest Territories, was carried out.

On the basis of these reviews and in consultation with the Government of the Northwest Territories a number of broad design goals were established:

1) Systems should be simple and be capable of being easily maintained and operated in severe climatic conditions by personnel with limited training and experience and with minimal resources and back-up.
2) Each system component should have at least one back-up.
3) Standardization of system components is highly desireable.
4) System design should recognize the short season, limited transportation facilities, severe climatic conditions, geotechnical constraints, limited local resources, and high costs associated with construction in Norman Wells.
5) System components should be designed to maximize shop fabrication and minimize on-site labour requirements.
6) Systems should be designed to minimize energy costs for heating.
7) Capital cost of systems should be kept to the minimum level consistent with the preceding goals.

3.2 Design Guidelines for Sewers and Watermains

As a further step firm guidelines were established for the design of the required water and sewer mains. These guidelines were based on knowledge available to the designers early in 1976 and in view of tight schedules a number of subjective decisions had to be made, sometimes on the basis of very limited historical information.

The following guidelines were used to establish system concepts for the utilities delivery systems:

1) Buried systems should be used wherever practical. These were considered preferable to above ground systems on the basis of lower heating energy requirements, lower vulnerability to vandalism and accidental damage, minimal disruption to community traffic patterns, better community aesthetics, and (it was hoped) lower capital cost.

2) Buried systems should be designed so that progressive thaw settlement does not occur.

3) In areas where above ground systems were necessary, they should be founded on pilings capable of resisting all forces (including heaving forces) without progressive movement.

4) Heat tracing should not be used on any new sewer or watermain. Previous government experience with electric tracing, either as a freeze prevention device or as a thawing method, indicated that it was extremely expensive to operate because of high unit costs for electricity in relation to other forms of energy and the inclination of operating personnel to leave the system turned on regardless of need. Hot water tracing and steam tracing were not considered practical within the context of the system goals.

5) Back up thaw systems should be available for both sewers and watermains.

6) Freeze prevention of watermains should be achieved by heating water at the source, using low cost energy, and recirculating wherever practical. Dead end lines should be avoided. Where new dead end lines are necessary, required minimum flows should be achieved by bleeding to sewers.

7) Watermains should be capable of being drained, prior to freezing, in the event of a major system failure.

8) Mechanical systems, such as sewage lift stations, should be avoided wherever practical.

The preceding guidelines imposed some severe constraints upon the system designers. Prior to proceeding with conceptual systems design two crucial questions had to be answered.

1. Are buried services practical in Norman Wells?
2. What pipe material will meet the guidelines and system goals?

3.3 Buried Services in Norman Wells?

Apart from grade considerations for both sewers and self-draining watermains, the primary factors in determining the practicality of buried utilities in Norman Wells were geotechnical. In particular the question of how to install warm water and sewer lines in ice-rich permafrost without initiating progressive thaw settlement required some hard answers.

Advice from specialists in thermal problems in permafrost was needed and the firm of EBA Engineering Consultants Limited was engaged to review the problem.

In order to determine the long term effect of warm pipes buried in permafrost a mathematical geothermal model was constructed utilizing a powerful, two dimensional, non-steady state finite element computer program which had been developed for the proposed Mackenzie valley gas pipeline. Input to the program included:

- transient (time dependent) meteorological data for Norman Wells
- snow and ground surface characteristics related to meteorological data
- thermal properties, both frozen and unfrozen for soil strata representative of the site
- thermal properties of the proposed pipe insulation
- operating temperature of the system

Results from the analysis indicated that a 150 mm pipe with 75 mm of polyurethane insulation at a steady state operating temperature of 16°C would result in a predicted long term thaw settlement of 150 mm maximum at the site under consideration.

The preceding thaw settlement prediction was contingent on several qualifications including the following:

1) Construction had to be carried out in the fall and winter when average air temperatures were below freezing to minimize thermal disturbance during construction.

2) Organic material excavated during trenching had to be replaced during backfilling.

3) At least 150 mm of non-frost susceptible bedding was required beneath the pipes.

4) Major surface thermal disturbances had to be avoided along the right of way in perpetuity.

It was decided that the construction of buried services would not be practical or prudent in areas where there were thick layers of poorly drained organics, granular blankets containing massive rock, or continuing sources of external heat (such as steam traps).

After reviewing both geotechnical and grade considerations it was agreed that buried services would be a practical solution for replacement of the old Public Works Canada utilidor system. In other areas an above-ground system would be required.

3.4 Pipe Material?

A number of materials were considered for use in the proposed system. These included PVC, asbestos cement, cast iron, high density polyethylene, ductile iron and steel.

Each material was evaluated against a set of criteria for both above-ground and buried service as follows:

1) Pipe should have a proven service record in similar applications.

2) Since no heat tracing was to be provided, pipe should be capable of being thawed by other conventional means such as energizing or steaming.

3) Water pipe should not require thrust blocking because of anchoring difficulties relating to thaw in buried systems and slender piles in above-ground systems.

4) Pipe for above ground applications should have high beam strength to allow maximizing of pile spacing without requiring secondary longitudinal structural support.

5) Pipe for above ground applications should have a reasonably low coefficient of thermal expansion.

6) Pipe should have a service life of at least twenty years.

7) Pipe should be capable of withstanding a freeze.

8) Water pipe should be capable of being easily tapped under pressure.

9) Pipe for buried services should be capable of withstanding differential settlements of up to 150 mm.

Although none of the materials met all the criteria a number were easily rejected. The list was reduced to HDPE and steel for buried services and ductile iron and steel for above ground services. A subjective decision was made and uncoated welded schedule 80 steel pipe was chosen as the most suitable material for the entire system. This material selection was consistent with materials used in the existing water supply and distribution systems.

4. SYSTEM CONCEPT

4.1 General

Once geotechnical constraints were identified and basic material selection was completed, development of system concepts proceeded rapidly.

In the interests of economy existing sections of the Government of the Northwest Territories utilidor system were incorporated wherever practical. For the same reason above ground water and sewer lines were designed to hang on the same pile supports and wherever practical buried lines were installed in closed proximity in a common trench.

Design capacities for both sewer and water systems are in excess of 400 m^3 per day. Current loading/demand is in the order of 170 m^3 per day.

4.2 Water System

The final concept for the water system is shown in Figure 4.

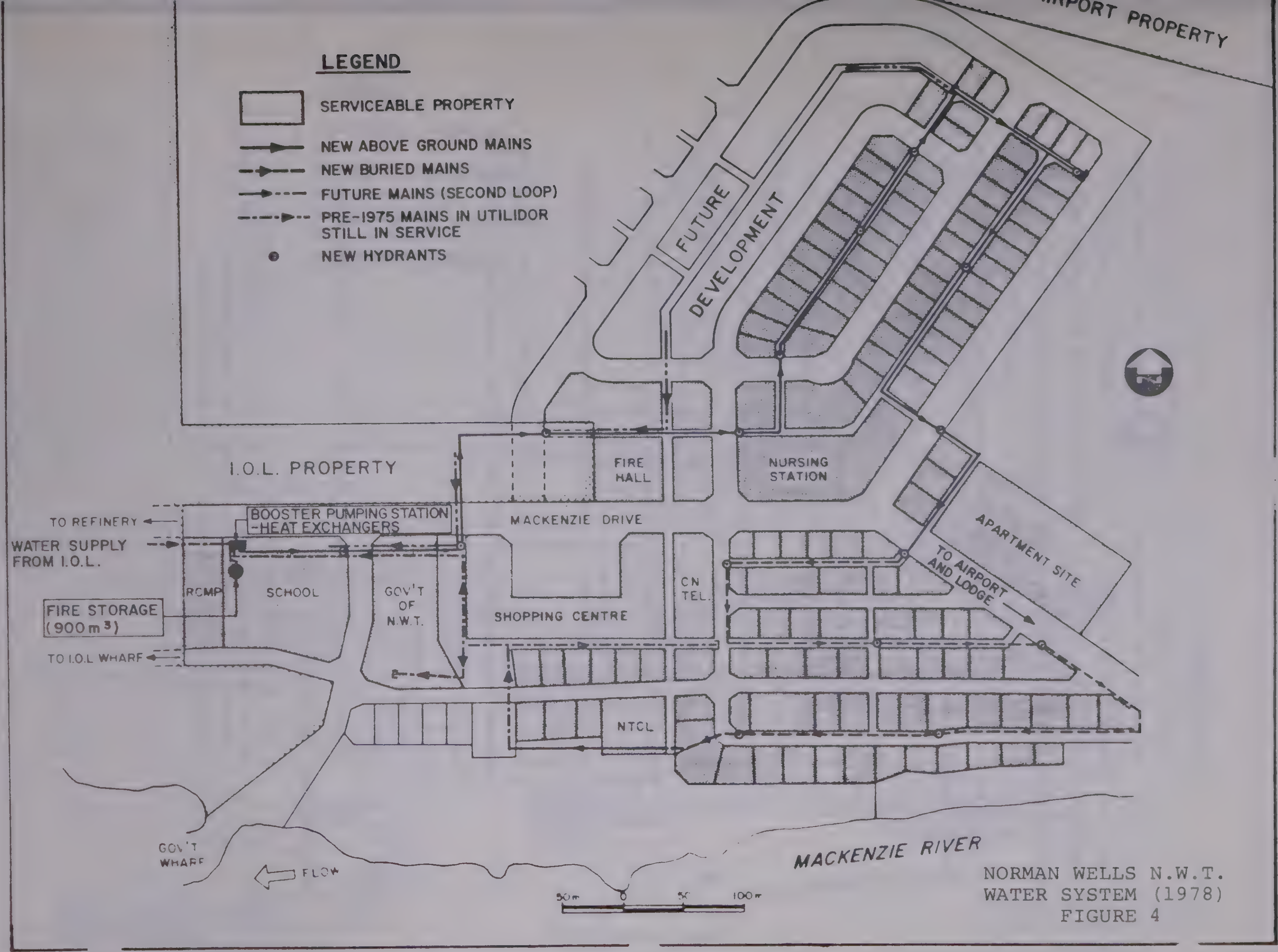
The essential elements of this system are a single loop circulating distribution main, pretempering facilities and circulation pumps located in the existing booster pumping station, and a large heated water storage reservoir.

Treated water is received from Imperial Oil Limited, pretempered to about 10°C (when necessary), and stored in the reservoir. From the reservoir it is circulated around the loop and back into the reservoir. Sufficient heating capacity is available to provide heat to the reservoir and mains, and to allow for heating of all present and future house service connections by recirculation.

Although the distribution system is essentially a single loop, three unavoidable 'dead' branch lines occur. The new branch line at the northeast end of the system is warmed by bleeding to the sewer system in winter and two pre-1975 branch lines in the south-centre of the community are still heated by hot water tracing. These branch lines could all be retrofitted with small circulation pumps and small diameter return lines if an alternate heating system was desired. Provision was made for relating easy addition of a second circulation loop to service future community expansion to the northwest. Buried piping is used to replace the old Public Works Canada system.

Key design features of the system include the following:

1) All distribution lines are graded to drain valves to allow easy draining in event of a failure.
2) All hydrants are on line to allow freeze-prevention by normal water circulation. Maximum hydrant spacing is defined by a 76 meter coverage radius.
3) Booster station piping permits feed to both ends of the circulation loop in the event of fire or freeze.
4) No expansion joints occur in distribution piping, eliminating the need for thrust blocking or anchoring. Flexible above ground supporting systems and service connections provide for thermal expansion.
5) Piping is fitted with conductors to permit thawing by energizing short sections of line.



NORMAN WELLS N.W.T.
WATER SYSTEM (1978)
FIGURE 4

4.3 Sewer System

The final concept for the sewer system is shown in Figure 5.

The essential elements of this system are well-graded sewer lines and improved disposal facilities. All sewage is brought to a common outfall and facilities are being constructed to provide maceration and submerged disposal well away from the shoreline.

The above ground segments of the system use the same supports as the water lines and buried piping is generally in the same trench as the watermains.

Key design features of the system include the following:

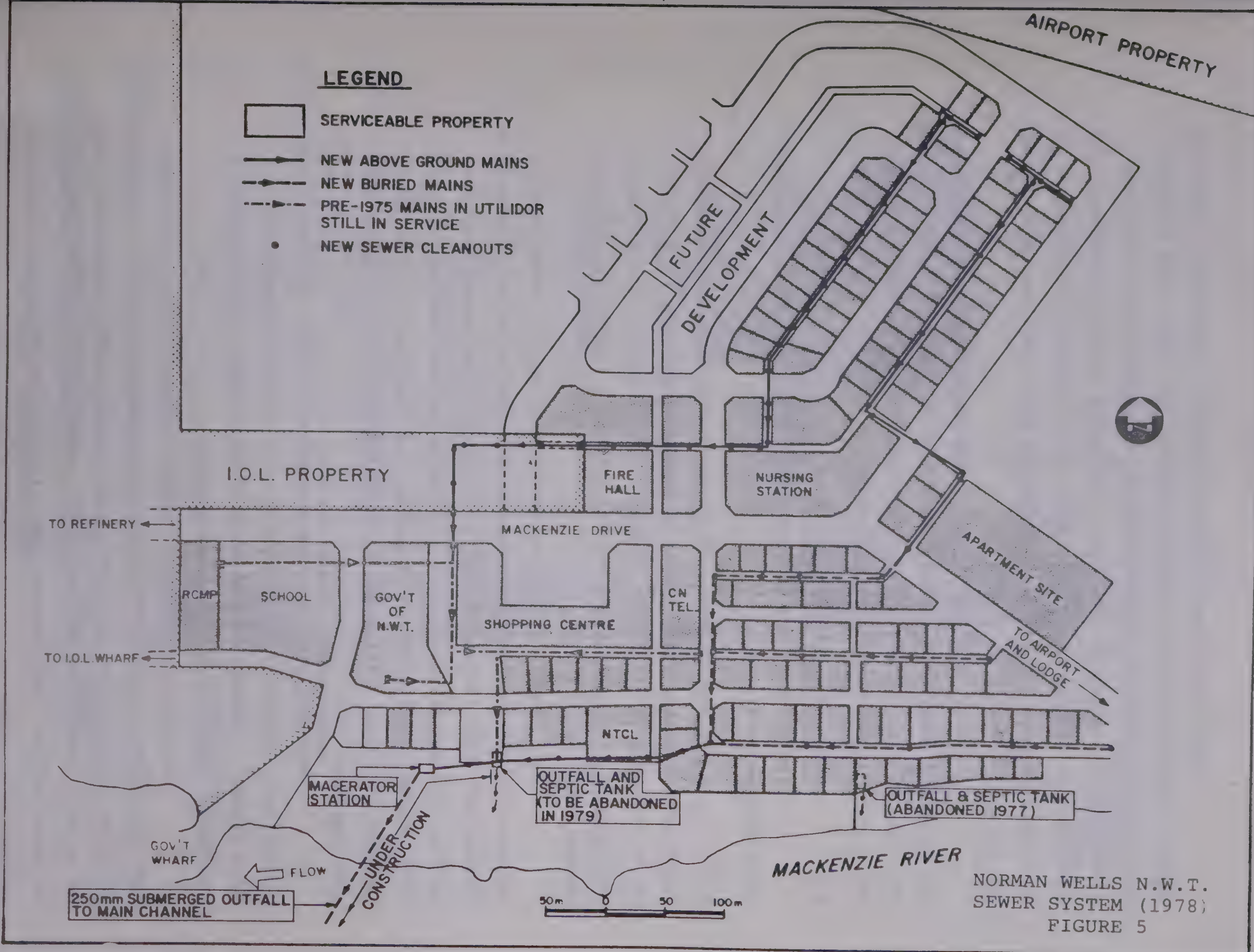
1) The sewage collection system is a closed system. All piping is pressure piping and there are no open manholes on the system. Venting is achieved through house services. This system was chosen in order to reduce heat flow into ice-rich soils and to eliminate ground water infiltration.
2) No auxilliary heat is provided to the system. Thawing can be accomplished by a portable oil-fired steamer.
3) Grades are maximized on the system. The minimum design grade is .75 per cent.
4) Access for cleanout is provided at intervals not exceeding 80 meters.
5) No expansion joints are provided in piping. Flexible above ground supporting systems and service connections provide for thermal expansion.

5. DESIGN DETAILS

5.1 General

The review of previous northern utility delivery systems brought home one point very clearly.

> *Although system concept is important, careful attention to design details is essential. Most of the failures that have occurred are the result of detailing inappropriate to the environment rather than of faulty system concept.*



NORMAN WELLS N.W.T.
SEWER SYSTEM (1978)
FIGURE 5

Apart from climatic and geotechnical constraints, the human factors and the limited resources available will often make a proven and standard "southern" design detail or component unacceptable and unworkable in a northern situation. Designing suitable components for a northern system requires innovation, good judgement, an awareness of both the human and natural environments in which they are to be installed, and a fair amount of good luck.

A number of design details used in the Norman Wells systems are presented along with comments on design rationale. Although there has been reasonable success with these details, one cannot generalize and apply them elsewhere without caution.

5.2 Main and Service Bundle Configurations

Typical main and service bundle configurations are shown in cross-section in Figure 6.

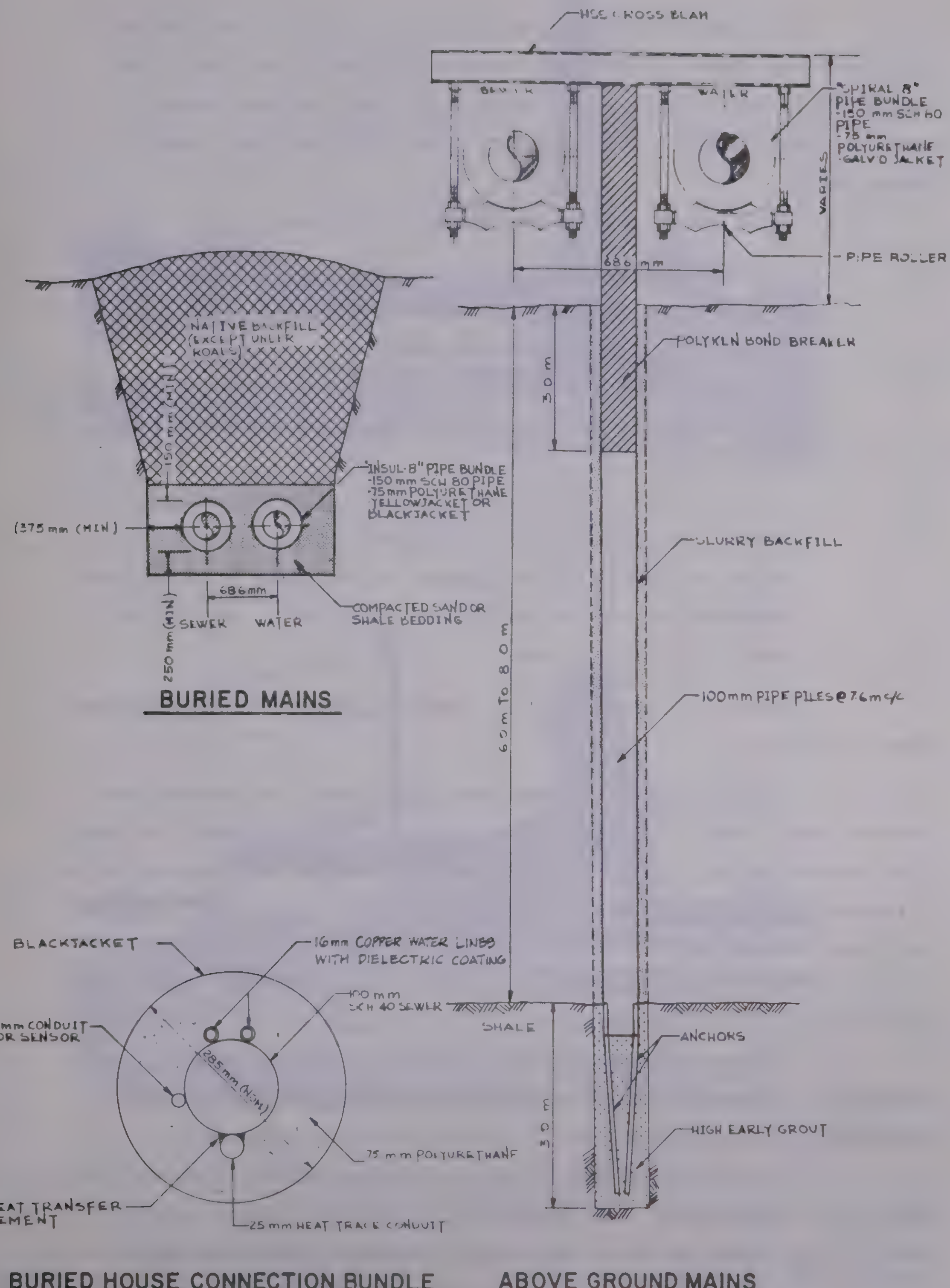
5.2.1 Above Ground Mains

The pipe bundle selected for above ground mains was the Shaw "Spiral 8" package consisting of a 150 mm or 200 mm schedule 80 steel pipe surrounded by 75 mm of factory foamed polyurethane insulation and a factory applied interlocking spiral galvanized steel jacket.

Pipe bundles were to be supplied in double random lengths complete with pre moulded polyurethane half-shells and split galvanized sleeves for field joints. Field joints were to be accomplished by welding, and galvanized sleeves were installed over half-shells using circumferential stainless steel banding and sheet metal screws on longitudinal seams. All seams were caulked with a high quality flexible compound.

This bundle and joining system was selected because it was weathertight, relatively vandal proof, and involved a minimum of field labour. In addition there was no requirement for longitudinal structural support or a separate enclosure.

In order to accommodate thermal movements (up to 200 mm on some runs) without resorting to expensive expansion joints or expansion loops, the bundles were allowed to move freely on their supports. This was accomplished by hanging them from cross beams using threaded rods and pipe rollers. The threaded rods also allowed for future field adjustment of grades.



TYPICAL CROSS-SECTIONS
OF NEW SERVICES
(1975-1978)
FIGURE 6

In view of previous problems with pilings, considerable attention was given to designing a pile that would not frost-jack. Geotechnical advice was sought and a design was evolved based on previous experimental work including some field pull-out tests in Norman Wells.

Key elements of the design are as follows:

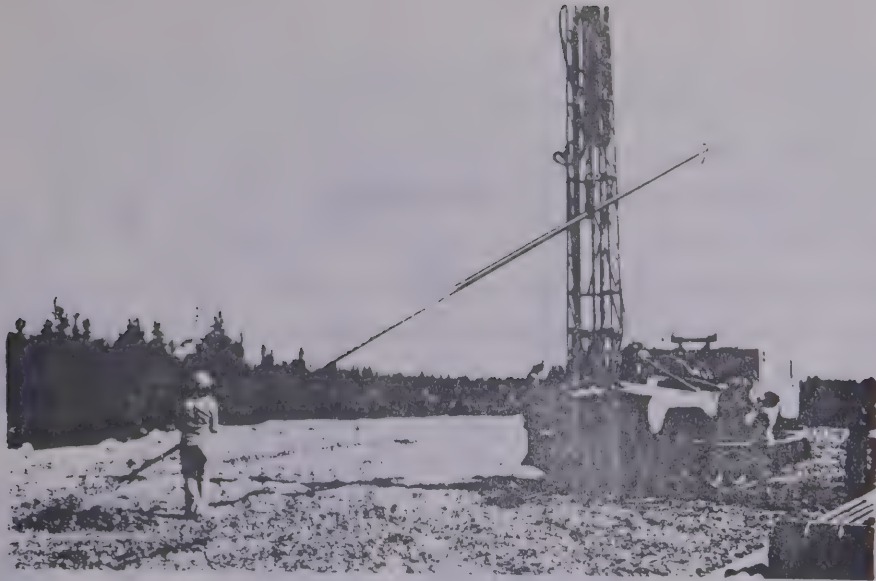
1) 100 mm drilled steel pipe piles were selected based on availability of material and limitations of existing drilling equipment in Norman Wells.
2) The upper 3 to 4 meters of the pile were wrapped with a smooth heavy polyethylene tape to reduce bond in the active layer.
3) The piles were fitted with grouted anchors extending 3 meters into the soft shale bedrock. Anchorages were designed to resist uplift forces in the order of 90 kN and involved the use of pre-heated, high-early, non-shrink grout in a frozen socket.

The piling operation and completed above ground mains are shown in Figure 7.

5.2.2 Buried Mains The pipe bundle selected for buried mains was the Shaw "Insul-8" package consisting of 150 mm schedule 80 steel pipe surrounded by 75 mm of factory foamed polyurethane insulation and a factory applied "yellowjacket" or "blackjacket" coating. Bundles were supplied in double random lengths and field joining was accomplished by welding and covering the joint with pre-formed insulation half-shells and polyethylene heat shrink sleeves.

The bundle and joining system was selected because it was reasonably watertight, capable of withstanding large differential settlements, and minimized field labour as much as possible.

The dimensions and quality of bedding material were based on geothermal requirements and protection of the relatively thin polyethylene jacketing material on the pipe bundles. Bedding had to be



Piling

Completed Mains

ABOVE GROUND MAINS

FIGURE 7

non frost susceptible, less than 6 mm in nominal dimension and preferably non-angular. Materials permitted by specification were clean sands and screened shales, however, the successful contractor neglected to arrange for supplies of these materials early enough and coarse angular shale materials were used for much of the bedding. As a consequence further protection for jacketing material and insulation was required and a 5 mm asphalt-impregnated fibreglass protective sheeting was banded over the bundles exposed to this coarse bedding.

Backfill consisted of frozen native material with organics replaced on top, except under roadways where compacted shale was used.

As mentioned earlier some existing roadways had been build on an insulating layer of spruce slash. In trenches through these roads, styrofoam insulation was installed to replace the excavated slash.

Installation of buried mains is illustrated in Figure 8.

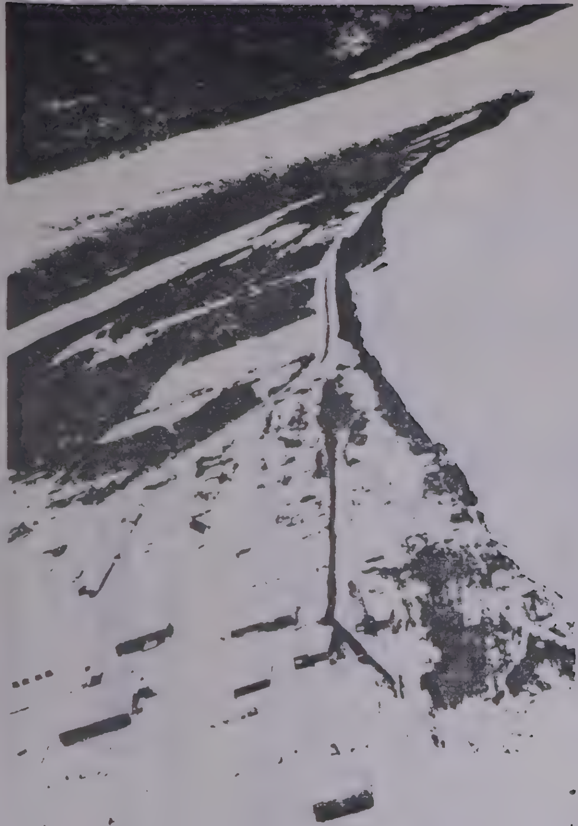
5.2.3 Buried House Connection Bundles House service bundles for buried applications are also shown in Figure 6. Again an "Insul-8" bundle with 75 mm of polyurethane was used.

Key features of this bundle are as follows:

1) Provision is made for supplementary freeze protection or thawing by thermostatically controlled 13 watts per meter electric heat trace cable at the 6 o'clock position of the steel sewer pipe.
2) Twin copper water lines are provided to permit householders to install circulation pumps and use warm water from the mains to heat the service bundle.
3) Water lines are coated with a dielectric to permit thawing by energizing the lines.

5.3 Service Boxes

Typical house service connection boxes are shown in Figure 9. Design criteria for above ground and buried boxes were quite different.

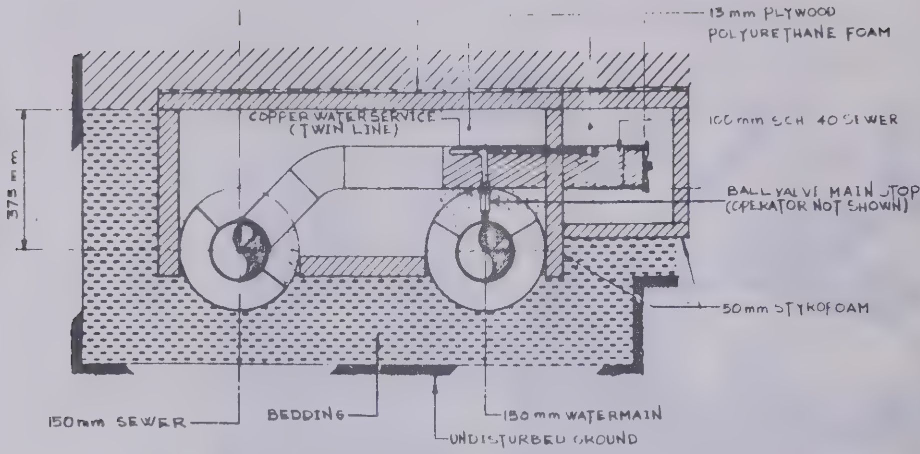


Excavation

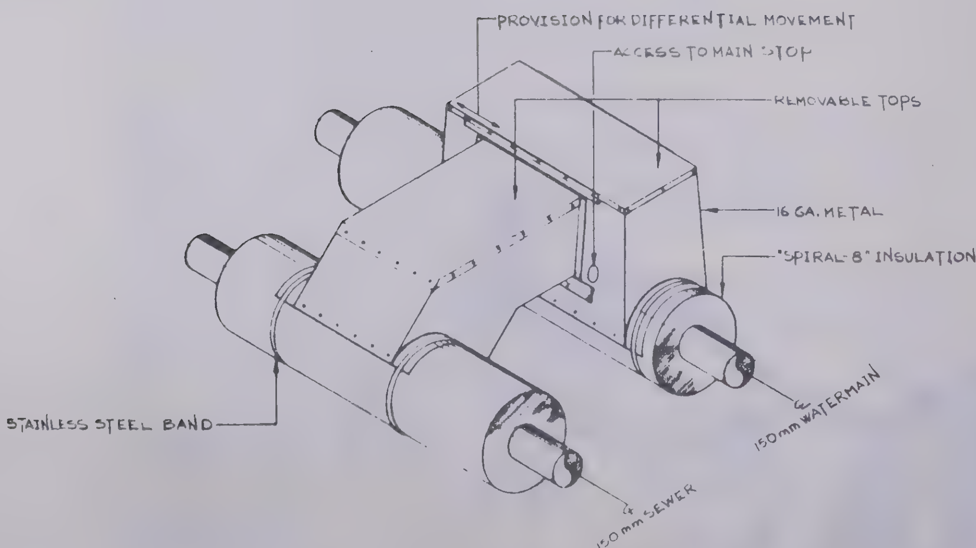
Cleanout Chamber and Insulated Pipe

BURIED MAINS

FIGURE 8



BURIED



ABOVE GROUND

TYPICAL SERVICE BOXES

FIGURE 9

5.3.1 Above Ground Service Boxes Detailed design of above ground service boxes was a major challenge. Apart from the goals of minimizing on-site labour, providing easy access, ensuring weathertightness and minimizing the possibility of vandalism; the designers were faced with the problem of differential movements of up to 7 centimeters between independently suspended sewer and water mains.

The boxes were shop fabricated out of 16 gauge galvanized steel as two separable halves interconnected by a sliding 'Track' device to permit longitudinal movement. Tops are removable for access and the entire assembly is mounted on the mains using stainless steel banding and sheet metal screws. All joints between boxes and mains are caulked with a high quality flexible compound.

Stubs for sewers were welded to the sewer main and provision for differential movement was made in the twin water services by using soft copper lines with large goosenecks.

Careful choice of insulating materials in the boxes was necessary. Foamed in place polyurethane and sheet styrofoam were used wherever possible; styrofoam beads were used in areas where freedom of movement was required.

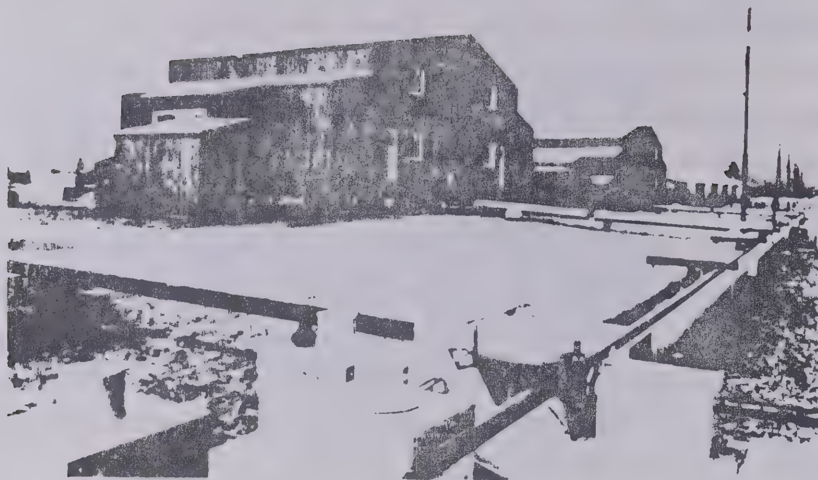
Finished and unfinished service boxes are shown in Figure 10.

5.3.2 Buried Service Boxes Ease of installation, strength and non hygrophobic insulation were the main criteria for buried service connection boxes.

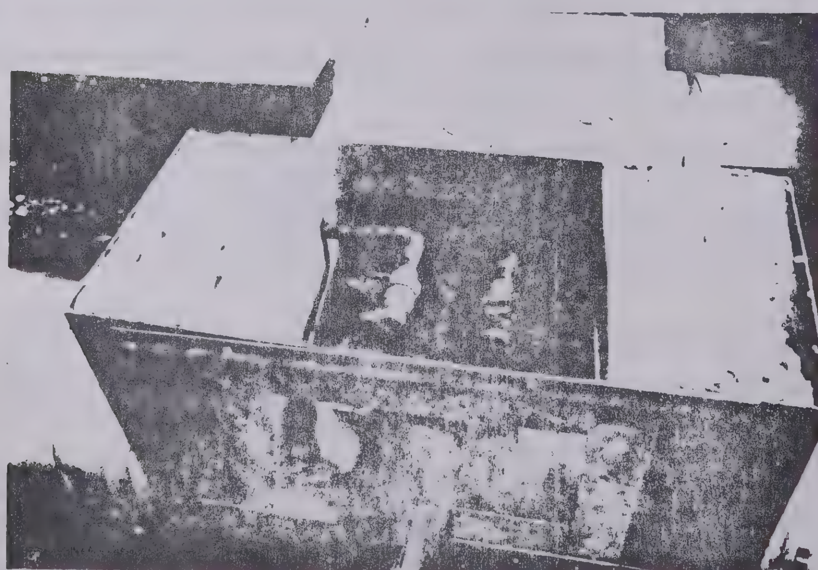
The typical design, shown in Figure 9, is a high density styrofoam box, filled with foamed in place polyurethane and covered with a protective plywood top.

The polyurethane foam was used primarily as a structural void filling material. The long term insulating value of this material in a submerged environment was considered minimal compared to the styrofoam sheets.

Differential expansion between buried sewer and watermains was not considered a serious problem, however, flexible goosenecks were incorporated in the water service lines.



Valves



House Service

ABOVE GROUND SERVICE BOXES

FIGURE 10

5.4 Hydrants

Typical above ground and buried hydrants are shown in Figures 11 and 12.

5.4.1 Above Ground Hydrants Above ground hydrants are enclosed in prefabricated, pre-insulated sheet metal enclosures, similar in design to house service connection boxes. The enclosures are fitted with quick opening "clamshell" doors secured by a hasp and pin.

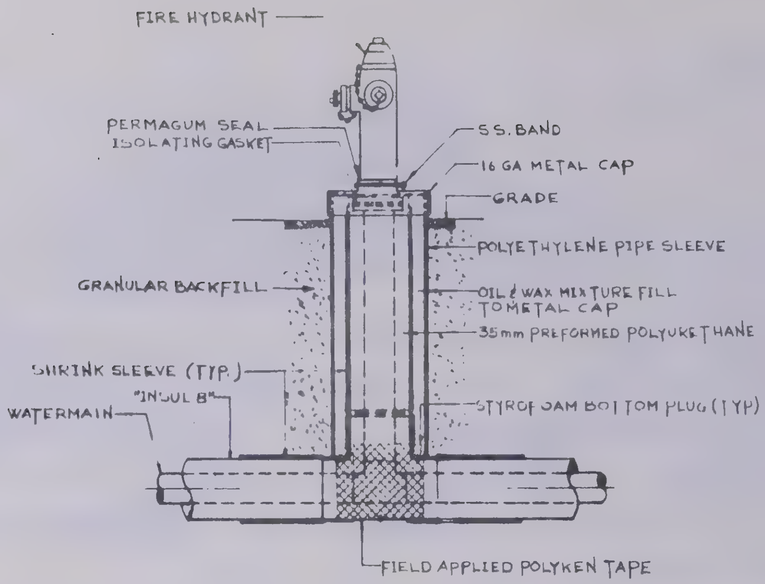
The hydrants consist of a 100 mm angle valve with a standard siamese attached. The angle valve was selected because it is essentially self draining. The valve is located as close as possible to the main in order that recirculating flow can keep the water beneath the valve seat from freezing.

5.4.2 Buried Hydrants Buried hydrants presented another challenge to the designers. Although standard McAvity on line hydrants were used as the basis for the design, modifications were required to suit the conditions found in Norman Wells.

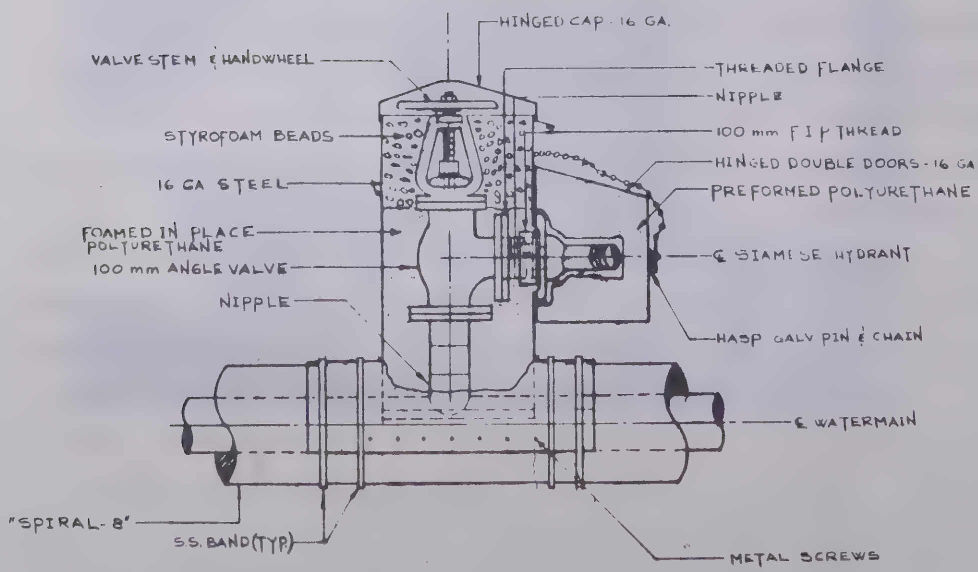
Because of concerns relating to drainage of hydrant barrels into ice-rich frozen ground, the drain holes on hydrants were plugged. The barrels were filled with propylene glycol antifreeze and insulated with polyurethane half-shells protected from moisture by polyethylene heat shrink sleeves. From an operational point of view barrels should be pumped dry after every hydrant use and refilled with antifreeze. The jacketted insulation allows for some time lag between the end of a fire and this maintenance requirement.

Another concern was the possibility that 'frost-jacking' of the hydrant barrel could cause a tensile failure of the hydrant assembly. In order to substantially reduce heaving forces on the barrel assemblies a series 45 HDPE pipe sleeve, capped at the top and gasketted at the bottom, was designed to fit over the insulated hydrant barrel. The annular space between the hydrant and the sleeve was filled with a viscous oil-wax lubricating mixture.

Pre-formed insulation half-shells were used on the tees connecting the "Insul-8" mains to the hydrants. Conformable polyethylene tape was used to provide moisture protection for the assembly.



BURIED



ABOVE GROUND

TYPICAL HYDRANT DETAILS

FIGURE 11

Buried

Above Ground

TYPICAL HYDRANTS

FIGURE 12

5.5 Road Crossing Structures

All above ground municipal servicing systems require some form of structure or culvert wherever road crossings occur. These crossings tend to be expensive and are often a continuing maintenance headache. The crossing structure developed for Norman Wells is shown in Figure 13.

Because of capital funding constraints it was decided that these structures would not be piled and that periodic maintenance relating to differential heaving and settlement was acceptable. This resulted in design requirements for a flexible structure that could be adjusted and maintained with a minimum of labor and equipment.

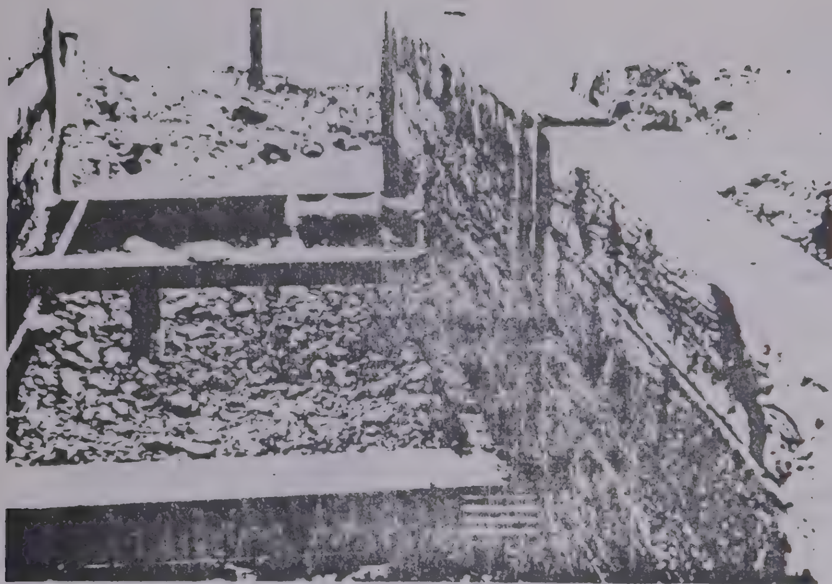
The structures were designed for AASHTO HS20 loadings with .2 to .6 meters of fill over the top. 'U-shaped' frames, fabricated out of H-pile sections and spaced at 3.7 meter centres, provided restraint for lateral pressures on the sidewalls. Sidewalls consisted of pressure treated douglas fir '8 x 8's' which fitted loose between the flanges of the adjacent steel frames, and a '3 x 12' fitted in the same manner served as the footing. Longitudinal steel angles welded to the tops and bottoms of the U-frames maintained spacing and alignment but were flexible enough to allow for differential settlements. Tops are removable and consist of 1.9 meter panels fabricated out of '8 x 8's' and '3 x 12's' with an integral waterproof sheeting to reduce dripping on the utilities. Relatively large vertical clearances were left between the piled piping systems and the unpiled crossing structures to allow for differential movement.

Structures were founded on .3 meters of compacted shale bedding.

Installation of these structures was able to proceed very rapidly due to the prefabricated 'drop-in' design.

5.6 Cleanout Chambers for Buried Services

For reasons previously mentioned, conventional manholes were not used in the Norman Wells buried system. The cleanout chamber design that was developed is shown in Figure 14.

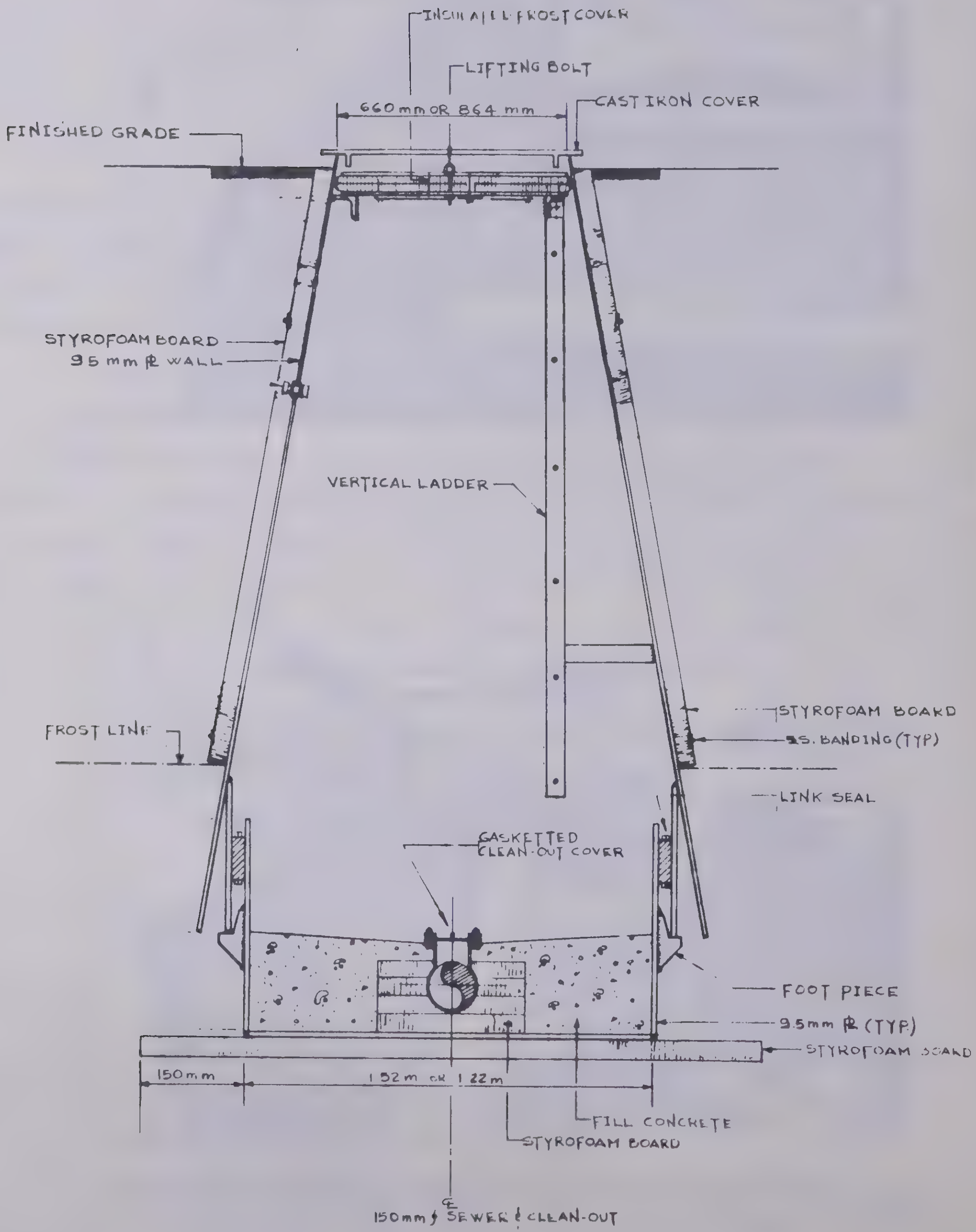


Piles, Rollers and Sidewalls in Place

Completed Structure Near Above Ground to Buried Transition

ROAD CROSSING STRUCTURES

FIGURE 13



CLEANOUT CHAMBER

BURIED SEWERS

FIGURE 14

The design is basically a two piece epoxy coated steel manhole containing a gasketted cleanout for sewer maintenance. Concrete was not considered a viable alternative because of the distance involved in shipping precast components and the unavailability of suitable aggregate in Norman Wells at the time of construction.

Important features of the design include the following:

1) Two piece construction was used to reduce the transmission of potential heaving forces to the main. For the same reason a "frost taper" of 10° minimum was introduced in the upper conical section.
2) Sealing between the upper and lower sections of the chamber was accomplished by removable bolted compression seals.
3) The top and sides of the cleanout chamber were insulated to slow conduction of surface heat to the lower permafrost layers.
4) Insulation around sewer pipes and under the base of the chamber reduces conduction of sewer heat into the subsoil, and the closed design eliminates ponding of warm sewage in the chamber.
5) Gasketted cleanout covers provide visual indication of any surcharge to maintenance personnel.

The chambers were designed so that all components could be shop fabricated in southern Canada, reducing on-site operations to a minimum.

5.7 Water Storage Tank

The site available for water storage facilities was one of the worst in Norman Wells. A geotechnical investigation revealed organics to depths of up to 2.1 meters, underlain by frost-susceptible, frozen, high moisture content silty clays and clayey silts. Bedrock was deeper than usual for Norman Wells; occuring at an average depth of 8.9 meters.

Because of the high costs involved in founding the proposed 900 m^3 tank, a detailed assessment of three alternative foundation types was carried out with the assistance of a geothermal consultant. Systems considered were:

- a structural slab with piles to bedrock
- a pad foundation thermally stabilized by heat pipes
- a pad foundation thermally stabilized by free convection ventilation ducts.

The vented pad was rejected on the basis of site location in relation to possible future buildings, and detailed geothermal computer analysis to determine basic requirements was only carried out on a pad stabilized by heat pipes.

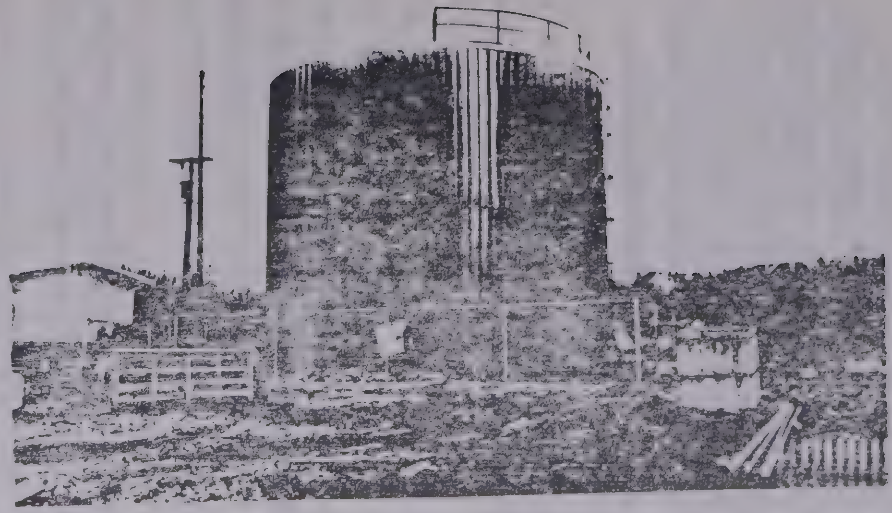
Preliminary designs were prepared both for piled foundations and for pads stabilized with heat pipes. Cost estimates indicated a saving of 50 per cent by using heat pipes and this method was chosen.

The final design for the pad was based on a tank operating temperature of 13°C and involved the following timing-sensitive operations:

1) Sub-excavation of all organics and native material had to be carried out to a predicted thaw bulb depth of 3 meters (during the fall so that subsoil would not be melted).
2) During late fall the sub-excavation was to be backfilled with non-frost-susceptible granular material placed in thin lifts and wetted to increase moisture content (and consequently volumetric latent heat). Aluminum ducts for the heat pipes were to be inserted in this backfill.
3) After allowing backfill to freeze for several months, 150 mm of high strength styrofoam insulation, covered by a sand blanket, was to be placed during late winter.
4) After fabrication of the tank on the pad during spring and summer, the heat pipes (McDonnell-Douglas "Cryo-Anchors") were to be inserted in the ducts, grouted in with a bentonite slurry and put into operation.

The partially completed tank and "Cryo-Anchors" are shown in Figure 15.

"Cryo-Anchors" Installed



Tank Nearing Completion

WATER STORAGE TANK

FIGURE 15

For reason of economy, the storage vessel selected was a standard API 650 vertical cylindrical steel petroleum products tank. The tank was internally coated with an epoxy material and externally insulated with 64 mm of sprayed polyurethane insulation. Roof insulation was protected by an elastomeric compound and 'vandal-proof' wall insulation was protected by prefinished steel cladding fastened to circumferential girts. "Cryo-Anchor" radiator sections were suspended from the tank walls.

The design operating temperature of the tank is 10°C. Heat is provided by recirculation lines from the adjacent booster pumping station.

6. CONSTRUCTION

6.1 General

Construction of the water distribution and sewage collection systems commenced in the summer of 1976 and water was first circulated through the loop in April 1977. These systems were essentially complete by the fall of 1977.

Construction of the water tank was carried out on a project management basis involving a number of contracts running from July 1977 to November 1978.

Construction of the sewage outfall and macerator station began in September 1978 and is expected to be completed by April 1979.

6.2 Buried Systems

Perhaps the most difficult phase of construction was the installation of the buried systems during the fall and winter of 1976-77.

Equipment and materials arrived in mid-September 1976 and as soon as air temperatures dropped below freezing the contractor began excavating using a large 1.9 m^3 hydraulic backhoe. The initial 100 meters of trenching went very quickly and then progress ground to a halt because of a series of minor equipment problems, grade control problems and personnel problems. By the time these problems were resolved several weeks of good weather had passed and frost depth had increased considerably. Despite extensive pre-ripping and pre-breaking, excavation became progressively more difficult and by mid-December, in -40°C temperatures and less than 50 per cent complete, the work had to be abandoned.

Work recommenced late in February 1977 and by pre-blasting rapid progress was made. However, an early spring with the accompanying sunshine and melt water soon began to cause serious thermal disturbance to the ice-rich trenches. Although work was completed as quickly as possible there was cause for concern.

6.3 Water System Start-up

Water system start-up in April 1977 revealed a serious defect in the system where a proven "southern" component, in this case AWWA cast iron gate valves, failed in a northern situation. Start-up was achieved by pumping warm water rapidly through the piping and bleeding off this initial charge at hydrants before it froze. Temperature measurements recorded at the time indicated that 35°C water entering the system was as cold as -2°C when it first hit the bleed point. Air coming out of the pipes ahead of the water charge was as cold as -31°C.

In reflection, a cast iron valve was no match for the stresses imposed on it in the Norman Wells environment. Thermal shock during start-up, combined with thaw settlement and dubious installation techniques resulted in failure of a valve body. All buried valves were subsequently replaced with forged steel models.

7. SYSTEM PERFORMANCE

Because of the uniqueness of many of the concepts and components in the Norman Wells utility systems, a reasonably close watch is being maintained by both operating and design personnel. As an aid to observations a number of thermistor stations were established when the system was constructed.

Based on the relatively short period of observation (less than two years) since the system was started up, a few preliminary comments can be made.

1) Temperature drops on the recirculating water system are less than forcast by the designers. The normal differential temperature between supply and return water in winter is 2°C.

The system normally operates at a higher temperature than required (17°C outgoing) because of steam traced supply from the source to the system. Supplementary heating at the booster pumping stations is seldom required. No freeze ups have occurred.

2) There has been very little trouble with the untraced sewer system. One freeze up has occurred near the upstream end of a branch in the buried system and a small bleed was subsequently initiated at the last house on the line. Temperatures at the sewer outfall are normally about 15°C.

3) A thermistor located beneath a sewage cleanout chamber in ice-rich soil indicates no advance of the thaw front in the past year.

4) Thermistor strings located under the 900 m^3 water storage tank indicate the heat pipes are operating satisfactorily.

5) A number of problems have been reported in house service connections relating to heat trace burnouts and failures of fractional horsepower circulation pumps. However, only one freeze up has been reported and this occurred within the house beyond the end of the service bundle.

6) Road crossing structures appear to be performing well. One structure, located near a steam trap, has experienced differential settlements in the order of .3 meters without distress.

7) Above ground service boxes appear to be accepting differential movements well except for one line where packed snow prevented expansion at a 90° bend. This caused excessive differentials at the far end of the line with consequent distortion of some boxes.

In general the performance of the system has been above expectations. Problem areas have been noted by the designers and will be taken into account in any further expansions of the system.

8. COSTS

Because of remote locations and harsh service requirements, the capital costs of northern utility delivery systems are high in relation to southern norms. Typical unit costs for some of the system components described in this paper are presented in Table I. These costs include supply of materials, installation and final engineering design.

TABLE I

UNIT CAPITAL COSTS

Item	$ per meter(foot)	$ per M^3(I.Gal.)
Buried 150 mm sewer and water mains in common trench, including all appurtenances.	\$577 (\$176)	N/A
Above ground 150 mm sewer and water mains on common piles including all appurtenances.	\$824 (\$251)	N/A
900 m^3 insulated heated water storage tank including foundations and all appurtenances.	N/A	\$360 (\$1.64)

When compared with historic cost data on systems installed in other remote communities, the preceding costs appear quite reasonable.

Total cost of the water and sewage systems described, when completed, will be in the order of $3.5 million including all engineering.

9. CLOSURE

The author hopes that the observations contained in this paper will provide some insite into the approach taken in recent designs for municipal services in Norman Wells, and that both the successes and problems encountered will aid other designers as northern utility systems continue to evolve.

10. ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance and guidance provided by Mr. A. Shevkenek of the Department of Public Works of the Government of the Northwest Territories, both during the design of the facilities in Norman Wells and in the preparation of this paper; and the major design contribution made by the late Mr. G. Goldschmidt who developed most of the details for the above ground and buried systems.

11. REFERENCES

Dillon, M. M. Limited, "Norman Wells, N.W.T., Water Supply Study and Extension of Services to New Subdivision". February, 1976.

Dillon, M. M. Limited, "Norman Wells, N.W.T., Sewage Treatment and Disposal Feasibility Study". April, 1978.

EBA Engineering Consultants Limited, "Pile Design for a Proposed Utilidor, Norman Wells, N.W.T.". April, 1976.

EBA Engineering Consultants Limited, "Proposed Buried Utility System, Norman Wells, N.W.T.". May, 1976.

EBA Engineering Consultants Limited, "Foundation Design for a Heated Water Storage Tank, Norman Wells, N.W.T.". March, 1977.

Government of the Northwest Territories, Department of Loca Government, "Water and Sanitation Costs - A Consolidation of Historical Information". October, 1977.